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LITERATURE OF THE LIFE SCIENCES: THE HISTORICAL BACKGROUND

DAVID A. KRONICK, PH.D.
Library Director
Health Science Center
University of Texas
San Antonio, Texas

To understand any phenomenon it is useful to know its antecedents. Physicians apply this principle when they take a history from their patients to establish a diagnosis. This approach may also be relevant to understanding the "body" or "bodies" of literature in the life sciences, as it is used in such expressions as the Hippocratic Corpus when referring to the literary works of the legendary and historic Greek physician who, in another allusion, is called the "father of medicine." Such expressions imply an organic nature to the literature and suggest that, like all organic forms, it has gone through a process of evolution which can be described historically. It also implies that by studying the evolution of the medium, we can more easily understand the more complex forms we see today. In the development of scientific communication, some of the species, as in all evolutionary processes, survive and continue to

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function although in some cases with changes attributed to changes in the social and scientific environment. Keele argued for knowing the history of a phenomenon in another yet similar manner. He compared history to a Bach fugue, because history, he said, "possesses a unique power of showing how the complexities of the present have evolved from relatively simple roots. It displays the logic of this growth, much in the same way as Bach presents us with a simple theme before confounding us with the contrapuntal wizardry of his fugue."[1]

In the history of scientific communication and of communication in general, no communications technique ever seems to be completely obliterated. It may even be enhanced by the introduction of new techniques. In the historical antecedents of our present communication systems, scientists and practitioners will easily recognize prototypes of media and communications practices which they use today. Oral transmission of information, our most ancient medium, is still one of the most used today, especially since enhanced and facilitated by electronic means and by the ease and speed of travel. In fact, historians of science lament the lack of the written records which in the past were available in the form of correspondence and diaries. As a result, our perceptions of how research is conducted and how new discoveries are made may be distorted. Historians of contemporary science must therefore depend on what they call oral histories, i.e., interviews with individuals who have been involved in particular scientific events.

Communications systems result from interactions between the perceived needs of its users and the available technology. There are, therefore, two lines of development in their evolution, extrinsic ones which relate to technical changes, such as improvements in roads and modes of travel, changes in means of producing documents through printing, photography or electronics, and intrinsic ones which relate to the changing philosophical basis of science, the roles of the scientist in society, and his modes of organization, education, and interaction. No comprehensive history of scientific communication has been written in these terms. In this essay we can consider only the major developments beginning during the long period which precedes the new approach to describing natural phenomena which emerged during the 16th and 17th centuries, characterized as the "scientific revolution," to the present, when science has become a highly developed and institutionalized part of our social and industrial systems.

The invention of writing is probably the most important technological

advance which occurred in communication. It very likely has not existed for more than five or six thousand years, and before this society depended entirely on oral transmission from one generation to another to retain its historical and technical heritage. In spite of this limitation, elaborate belief systems and an impressive technology developed involving agriculture, astronomy, the ability to manufacture both domestic utensils and instruments of war. Oral transmission of ideas as a primary medium has persisted through the ages even after the invention of writing and, millennia later, of printing. This is particularly true of the knowledge of crafts, passed on through apprenticeship systems and seldom made a part of the written record. The Académie des Sciences in Paris recognized this in the 18th century when it started a massive effort to collect and to publish information on the various crafts of the time, from wig making to coal mining. From this effort they published an impressive series of monographs in some 103 numbers under the title *Descriptions des Arts et Metiers* (Paris, 1761–1788).

Oral transmission of information continued long after the invention of printing, most likely due to scarcity of books. It was the tradition for professors in the medieval universities to read to their students from established texts and for them to transcribe the lectures, a system which persists even today in our lecture halls. It is difficult to say how much of our knowledge is still transmitted orally and never committed to paper. This is certainly true of some of our social beliefs, and it may also be true even of some of the technical aspects of the laboratory. It has been suggested that the scholarship of preliterate societies, based on oral transmission, tended to be nonanalytical because only when ideas are embodied in a static physical form can they be organized, analyzed, and explored.

Although writing introduced the ability to fix ideas in a static physical form, some of the problems of oral transmission remained, because manuscripts are disseminated by copying and errors of transmission easily occur. Now as in the past, original authors may also fall victim to the editorial zeal of copyists who may wish to "correct," amend, or even change the text.

One of the earliest scientific manuscripts we possess is the Edwin Smith papyrus, named after the man who acquired it in Egypt in 1862. Translated by the famous American Egyptologist, James Henry Breasted, and published in facsimile with a hieratic and English text in 1930, it dates from about 1500 B.C. but is probably based on older texts going back to

3000 B.C. It includes, for example, explanations of words whose meaning had already become obscure when it was compiled. The Smith papyrus, now in the Library of the New York Academy of Medicine, is one of eight principal Egyptian medical papyri so far discovered and studied. Containing a series of surgical cases with descriptions of the injuries and prescriptions for treatment, it is obviously only a fragment of the whole text, because cases are arranged in the traditional head to foot sequence and it stops about in the middle of the body. Each case description is accompanied by a statement about whether the physician will or will not treat it. At first glance this may seem a precaution against charges of malpractice, particularly considering the severe penalties we find in some texts of this period.[2] It has been explained, however, as an option traditionally exercised by physicians and recognized as late as the 18th century.

Another Egyptian medical text of about the same period, the Ebers papyrus, is concerned with nonsurgical problems. One chapter is headed: "Eye diseases treated according to the priest physician as revealed by a Semite of Kepni." This indicates that medicine even in this early period was international in scope.

A prominent American referred to the Smith papyrus almost with awe:

> Conceived in ancient Egypt about 5000 years ago, it is the most remarkable book in the entire history of surgery. Compiled by an unknown writer at a time when medicine was magico-religious, when the vocabulary of science had not yet been created and when the first groping steps in inductive reasoning were being taken, this volume is as logical as a modern textbook in surgery.[3]

It is difficult to know the relationships between any of the texts of the manuscript period unless earlier versions exist. These are lacking in many cases. It has been estimated that of all the literary writings produced by the classical Greeks, only about 10% have survived. For instance, the oldest manuscript we have of the work of Hippocrates was copied during the ninth century A.D., more than 1,000 years after his era. The whole corpus of Hippocrates' writing consists of some 100 treatises, many written by his students and their descendants, but considered to be of the school of Hippocrates rather than by the great physician himself. Others apparently were notes taken by his students during lectures, a practice which did not stop even with the introduction of printing. Many student notebooks transcribed from lecture notes taken as late as the 18th and 19th centuries have found their way into library collections, and some even formed the basis for textbooks.

The deficiencies of the manuscript period exist in the process of making copies. The reader has no assurance that his text is exactly that produced by the author or a copy in the possession of another reader. Texts were transformed in the process of making successive copies and reinterpreted through successive commentaries.[4] Each copy, in a sense, constitutes a new edition in which the copyist can exercise and perhaps abuse his editorial prerogatives of correction, expurgation, and emendation without the author's approval. Manuscript texts thus were subjected to endless alterations, additions, and abridgements. They were frequently brought together in collections of diverse and sometimes disparate items. Transmission of scientific ideas was largely through a process of synthesis, and many encyclopedic works on science and medicine were produced in this way from the Roman through the medieval period. Medieval writers borrowed freely and without acknowledgement from other compilers who in turn had borrowed from other sources until remote origins are lost in antiquity. In fact, the ideas of some of the classical writers survive only in the form in which transmitted by these encyclopedic compilers. These practices have not necessarily disappeared in modern times, and some of our scientific ideas may be transmitted in the same way through textbooks. Excerpts from published texts paraphrased or quoted out of context may be subject to the same abuses as the copied manuscript.

An established trade in books existed during Greek and Roman times. Manuscript copies could be turned out quite cheaply, since they were copied in large shops staffed by slave labor. In some ways this method of production had advantages over our system of publishing. A "publisher" could turn out a book almost at a moment's notice. The author handed his manuscript to the publisher, who turned it over to his staff of slave readers and transcribers. If a comparatively short work, it could be ready for distribution in 24 hours without the expense of typesetting or printer's corrections. Estimates have been made that some books in the manuscript period were produced in editions of 500 to 1,000 copies, which is larger than many of the editions produced by the early printing presses.[5] Texts were often borrowed verbatim without any acknowledgement of the source. Other texts maintained their identity, if not their integrity, for a long time. There is, for example, a text of the physician John of Bordeaux of which the British Museum alone has 22 manuscript copies, 17 in English, four in Latin, and one in Dutch, the

earliest dated 1365, and one copied as late as the 16th century.[6]

Use of manuscript books persisted long after the introduction of printing around 1450, and reflects the cultural lag that often accompanies technical innovations. Objections were also raised to printed books on scholarly and aesthetic grounds, although some equalled and even surpassed in beauty many of the manuscript books on which they were modelled. The great advantage claimed for the printed book—that it could replicate identical copies of the same text—was valid only if the original text was properly edited and composed. In their haste to meet market demands, the early printers often did not take care to produce accurate editions. Manuscript copies were sometimes made from printed books, which may still have been the cheapest way to produce a limited number of copies before the advent of photocopying.

The introduction of printing, however, ultimately radically transformed the nature of scholarship and the transmission of information. Texts available in identical copies could be disseminated more widely than had been possible with manuscript books. It was not only a matter of being able to reproduce texts more easily—authorship could be more readily established and ascertained. A recent writer aptly sums up the impact of printing on scholarship:

> First, it enabled priority of discovery to be established by referring to any copy of a printed text. But his can be done only if the text is accurately dated, and if the author is clearly named. Hence, the accurate establishment of priority of discovery depends on the development of conventions of presentation which record the authorship and date of published works.... The possibility of achieving a definitive version of a text, through its publication in a uniform edition of identical copies, also enables research results to be criticized, validated by replication, and incorporated into an accepted body of knowledge by citation.[7]

These changes in scholarship were as much due to changes in attitudes toward the writings which had been inherited from the past as in changes in technology. It is said that up to the Renaissance no sense of personal property in a piece of knowledge existed. The scholastic method consisted largely of the analysis and citation of authorities. In fact, many genuinely original works were published under the names of earlier well-known writers, because an established name conferred an authority which it might otherwise not have.[8] Although scholars are finding more and more expressions of original ideas in the Middle Ages, it was a period of faith in which the ancient authorities were for the most part accepted unquestioningly. The great German physiologist Helmholtz recognized

that this phenomenon still existed during the 19th century, when he remarked that a large part of our knowledge is still "accepted uncritically and without examination, indeed unconsciously from the past."[9]

It was not only the introduction of printing that ushered in an age of improved communication. Also involved were improved transportation and travel, as well as the growth of centralized governments which brought about such changes as better postal services. It is indeed difficult to say whether improvements in communications or the radical changes in attitudes toward the authoritative teachings of the past brought about the "scientific revolution." Travel in ancient times was one of the primary new methods of acquiring new knowledge. There was a certain amount of mobility in the ancient world, but the political unity imposed by Roman rule facilitated greatly the exchange of ideas among scholars. With the breakdown of the Roman Empire, the medieval church took over this function until the growth of the great national states.

Improved transportation and postal services helped greatly to increase communication among scholars. Scholarship recognized no political boundaries and the only qualification was dedication to the pursuit of knowledge. Vesalius, whose book on anatomy (published in 1543) is one of the landmarks of modern science, was born in Brussels. No country in Europe, however, can really claim him as their own. He studied medicine in Paris and taught anatomy in the universities of Italy. When it came time to print his great book, he sent the engravings, painstakingly executed in Padua, by caravan across the Alps to Switzerland, and then followed himself to see it through the press. He served in the latter part of his life as a physician of the Imperial Court in Spain, and died in 1564 while on pilgrimage to the Holy Land.

Vesalius exemplifies another important change which took place in the Renaissance, the beginning of the coming together of scholars who worked with ideas and words, and of craftsmen who worked with things and with their hands. This change can readily be seen by comparing the title page of the *Anathomia* of Mundinus, completed in 1316, although not printed until 1487, with the celebrated title page of Vesalius's *De Fabrica Humani Corporis* printed in Basle in 1543. In Mundinus, the physician sits on a platform high above an amphitheater where an assistant performs the dissection, whereas in the *Fabrica* Vesalius stands at the table performing the dissection himself.

Medical books were well represented among the first printed books

because, aside from the clergy and lawyers, physicians were one of the largest literate classes in Europe. Medicine also was a part of the academic background of educated men, and even nonmedical readers were interested in medical books as a part of their general interests. Medical books, therefore, were a fairly good investment for early printers who then, even as now, had to show a profit or close shop. Many early books printed popular texts that had existed in manuscript form for centuries, but contemporary authors also began to publish their works.

Before the 17th century, the literature of scholarship was comparatively static. Represented by a relatively fixed body of knowledge, although constantly modified by commentaries and recast into new encyclopedic collections, it remained of relatively the same order of size as preceding bodies of knowledge. With the emphasis on experiment and personal observation, introduced by such men as the philosopher Francis Bacon in the 16th century, a new element was introduced. The need to report each observation as a separate entity began to take precedence over the tendency to incorporate them into larger syntheses, especially as the means to do so became available through improvements in communications. There was a new sense of urgency which did not characterize the earlier period, where scholarship was regarded as the celebration of old knowledge rather than the heralding of the new. This was exemplified by a new pioneering spirit in science in which each scholarly adventurer sought to stake a claim in the new territory he was exploring. In this environment the ideas of progress and change went hand in hand with the changes in the nature and transmission of information.

The first medium available to scholars to disseminate new information before the revolutionary emergence of scientific journals during the latter half of the 17th century was personal correspondence. Personal in that it was usually addressed to an individual, it was also impersonal in that it conveyed news about observations and experiments in science rather than personal events. It introduced a new genre, the erudite letter, a letter intended frequently for a broader audience than the individual to whom it was addressed. It forms one of the important influences and precedents in the development of scientific journals, which today retains some of these functions in letters addressed to the editor, as well as in the research and other papers which can be regarded as letters addressed to a relatively undifferentiated and untargeted audience.

Sigerist suggests that the erudite letter continued to serve a purpose even

after scientific journals appeared:

> When a scientist made a discovery in the 18th century, he did not publish it immediately but described it in a letter written in Latin that was sent to some friends abroad. They in turn would discuss these letters with their students and colleagues, would repeat the experiments described and report what their experience had been. After a discovery had been tested in such a way, it might then be published in a monograph, or in the transactions of an academy.[10]

The volume of such correspondence during the 17th and 18th century (not all of which took place in Latin, although that was still the preferred language for international communication) is indicated by the bulk of some of the collections of letters of individual scientists of this period. The Danish physician, Thomas Bartholin, who also issued one of the early medical periodicals from 1673 to 1680,[11] published five volumes of his correspondence during his lifetime and was preparing to publish three more when his manuscripts were accidentally burned in 1670. Haller's letters fill seven large volumes and include some 13,000 letters to more than 1,600 correspondents in French, German, English, Italian, or Latin, all languages he used with ease.

To these erudite gentlemen, international conflicts imposed no barriers. The Dutch microscopist Anton van Leeuwenhoek continued to send letters to the Royal Society of London during the 17th century, although Holland and England were at war. Much of this correspondence was in fact addressed to the new scientific and learned societies which were beginning to be formed during the latter half of the 17th century. In some cases both the society and the correspondence were managed by the same individuals who became the editors of the early scientific journals. Henry Oldenburg, a preeminent example of this class, was first secretary of the Royal Society of London as well as the founder of the *Philosophical Transactions*, which appeared in 1665, three years after the Society received its Royal charter. His published correspondence filled 11 volumes in 1977, when the editors anticipated that at least two further volumes would be required.[12] They include letters to and from the leading scientists of Great Britain and the continent, including Robert Boyle, Edmund Halley, Robert Hooke, Martin Lister, Christopher Wren, Christian Huygens, Anton van Leeuwenhoek, Gottfried Wilhelm Leibniz, Marcello Malphigi, Francesco Redi, and Baruch Spinoza. These letters were to a large extent intended for members of the Royal Society with whom he shared them. They provide fascinating insights into the scientific life of the 17th century. The letters were entered in the Record Books of

the Society, but many also found their way into Oldenburg's new *Philosophical Transactions,* where he shared them with a wider readership.

Another technical innovation that preceded the first scientific journals were the media, which established predictable channels of communications and created "periodicity in print." These came in various forms such as annual book catalogs published for the various European book fairs soon after the introduction of printing. Manuscript and printed newsletters were issued for a select clientele on a regular basis. Among the paramount forms were the calendars and almanacs which provided annual vehicles not only for lists of phases of the moon and saints' days, but included such things as agricultural and health information and advice. Printed newsletters could also serve as vehicles of scientific information. It is sometimes suggested that in 1608 Galileo first learned of a device to see objects at a distance from a 12 page Dutch newsletter, a little larger than a library catalog card: included in an account of the visit to Holland of an embassy from Siam was a short note about the use of a combination of lenses that made distant objects appear closer.[13]

Newspapers were widespread by the middle of the 17th century. The first French newspaper was issued by the crusading physician Theophraste Renaudot (1586–1653), who issued the *Gazette* under the auspices of the government in 1631. His sensitivity to the conditions of the poor led to other innovations, including a public health clinic and other activities which provoked the bitter enmity of the medical establishment represented by Guy Patin and the Faculty of Medicine of the University of Paris.

The early newspapers, even as they do today, carried news of interest to the scientific community, but it was not until 1665 that the first two journals which can be regarded as true organs for the dissemination of scientific ideas appeared. The *Journal des Sçavans,* as it was then called, appeared in Paris. The Académie des Sciences had been formed shortly after in the same city, and, although it had no formal association with the *Journal,* news of its activities did appear in its pages. Although it did report scientific discoveries such as Jean Denis' curious experiments with the transfusion of blood and other scientific news gleaned from their correspondents, it was more a general literary journal than a scientific one. It was primarily concerned with reviewing books in every field of knowledge, except for those on religion and politics, which the editors treated very gingerly. The *Journal* was soon reprinted in Amsterdam and

other places and became a model for literary journals in Holland, Italy, Germany, and throughout Europe.

The Académie des Sciences pursued another course by publishing its proceedings in quite a different format, which in turn became a prototype for similar publications by other learned societies on the continent and later in America, including this *Bulletin.* Both the *Philosophical Transactions* and the *Journal des Sçavans* celebrated their three hundredth anniversary in 1965 although in quite altered form. The *Journal des Savants* today is a general literary journal, and the Royal Society now uses the *Transactions* to publish two series of highly specialized monographs, one in mathematics and physics, and the other in the biological sciences.

Modern commentators assign a high importance to the appearance of the journal in the history of science. Ziman puts it most emphatically: "The invention of a mechanism for the systematic publication of fragments of scientific work may well have been the key event in the history of modern science."[14] Cole and Eales say pretty much the same: "It may, in fact, be claimed that science could not have made the advance that it has but for the recognition of the periodical as the most convenient and efficient method of encouraging research."[15]

In many ways the scientific and learned journals of the 17th and 18th centuries did not resemble very closely the research journals we know today. Borrowing from one journal to another was a common practice. For the most part, sources were acknowledged but frequently no indication of origin was given. Sometimes the borrowed information is paraphrased and commentary added, and in this respect they were very much like the newspapers which provided their models. They did not worry about redundancy because they regarded themselves principally as news media. Duplication of information becomes a problem only when its recipient has access to both sources. This poses an interesting difference between the newspaper and the scientific journal in that the quality of a newspaper is improved to the extent that it includes information from other media, because it is often a unique source for a particular reader. A scientific journal, on the other hand, particularly one publishing original research, is proscribed from this practice. In the 17th and 18th centuries, journals were not as closely differentiated from monographs as today and were frequently reviewed in the same manner. This reflected that in some instances a large part of the content of a journal issue could be attributed to the editor, who sometimes referred to himself as the author. They were

also characterized by short life spans, and many did not last beyond the second or third year, perhaps because many appeared under the auspices of a single individual.

Specialized journals began to appear very early in the history of scientific journals, although much scientific material continued to be reported in general learned journals. Among the first specialized journals was one edited or written by another controversial French physician, Nicolas Blegny (1652–1722), regarded by some historians as rather unsavory although also credited with outstanding work on hernias in the 17th century and other interesting social and medical innovations.[16] His *Nouvelles Déscouvertes sur Toutes les Parties de la Médecine* appeared in 1679 in the form of letters to a provincial physician. It can also be considered an example of how scientific journalism can be used for self aggrandizement as well as to disseminate information. Blegny took care in some of his discussions of new drugs to indicate where they could be obtained, and was not constrained from speaking well of a new kind of hospital he had opened.[16]

The earliest specialized journals were medical because physicians were the largest organized group interested in the new science. Journals also fostered the intellectual and social status of a specialty. The Académie de Chirurgie organized in Paris in 1731 to support the surgeons' claim to academic standing began to publish the *Mémoires pour les Chirurgiens* in 1736. Specialized journals in other disciplines did not begin until later in the century. The German chemist, Lorenz von Crell (1744–1816) published his *Chemisches Journal* in Lemgo from 1778–1781 and followed it with other journals in chemistry. In London William Curtis (1746–1799) began his *Botanical Magazine,* still avidly sought by collectors today for its beautiful colored plates, in 1787. Before the end of the century there was even a journal in psychiatry, what the Germans called "knowledge of the soul," the *Magazin der Erfahrungsseelenkunde,* edited by Carl Philipp Moritz from 1783 to 1793 in Berlin.

The predominance of independent journals, those not sponsored by scientific or learned societies, continued throughout the middle of the 19th century although society sponsorship became more prevalent as time went on until today the situation is quite the reverse in that most journals are sponsored in some way by societies. The famous Danish physician Thomas Bartholin (1616–1680) published his *Acta Medica et Philosophica* from 1671 to 1680 while a member of the faculty of the University of Copenhagen, but the journal had no official connection with the school.

Early scientific societies nevertheless had a strong influence on the development of scientific journalism, and both responded to the same intellectual and social needs.

It is therefore more than a coincidence that the earliest journals arose in close association with scientific societies. The Royal Society of London contented itself with the *Philosophical Transactions* to disseminate news of their activities. The Académie des Sciences in Paris, however, published their proceedings in a series of *Histoires et Mémoires.* These, in a sense, formed an archival record of the activities of the society as well as a repository of the most important papers delivered in person or communicated to the society. They were often, however, published sporadically or very irregularly, or long after the papers were presented and sometimes not at all. The *Histoires et Mémoires* of the French Academy formed a model for the scientific and learned societies which proliferated in the French provincial cities throughout the small and large German towns and elsewhere in Europe. To a large extent they are more accurate prototypes of modern scientific journals than the independent journals published at the same time. Some current editorial practices, such as peer review, began in the methods these early societies devised for accepting communications for publication.

Booth argues that the Royal Society of London first "introduced the concept of refereeing" in the middle of the 18th century by setting up a committee to review all papers before they were published in the *Philosophical Transactions.*[17] There were, however, many antecedents to this practice. Oldenburg screened communications for presentation to the Society, but after the papers were read, they were "ordered to be reviewed by several of the Fellows."[18] The Académie des Sciences in Paris, early in its history, established select committees to determine whether a member could or could not publish under its auspices. The peer review process almost as we know it today is described in the preface to the French edition of the *Medical essays and observations* published by a "Society in Edinburgh" in 1731. Papers submitted, it informs us, are distributed according to their subject content to those members of the society who are more versed in these matters for their review. It also specifies that the identity of the reviewer is not made known to the author, an early example of the controversial anonymous reviewer.[19] The Société Royale de Médecine, soon after its institution in 1776, inaugurated a system by which two members examined each paper submitted to the society and provided the other members with a summary and critique.[20]

Validation of scientific work through review and discussion was in fact a major function of early scientific societies.

Reasons for the formation of scientific societies may be sought in generally gregarious human nature, but another important reason was failure of contemporary universities to respond to the scientific revolution. These organizations of individuals interested in the new science were sometimes called "invisible colleges" because they carried on some of the traditional functions of the university outside their precincts.

Some early scientific societies required contributions of papers as a condition of membership. Many also gave prizes for essays submitted on questions proposed by the society and widely publicized through general and special periodicals. These prize essays, in many ways can be considered closer precursors of modern scientific papers than any other 18th century publication format. They can to some extent be regarded as a form of sponsored research, clearly evident in prizes awarded by such organizations as the Royal Society of Arts (originally the Society for the Encouragement of Arts, Manufactures and Commerce), which from its origins in 1754 offered prizes for essays on such subjects as the improvement of the production of wine and the development of a more efficient ship's pump. The Society of Arts and Science in Utrecht proposed a question in 1783 with a decidedly modern inflection: What are the causes for the increase in nervous illnesses, and which causes lie in nature and which in the mode of life? They offered a prize of 30 ducats and expressed their willingness to receive papers in Dutch, French or Latin.[21] The venerable Faculty of Medicine in Paris, stimulated at last by the activities of the newly organized Societe de Medecine to publish an account of their public meetings, in 1778 announced that awards had been made for essays submitted on the subject of the treatment of miliary fever in pregnant women. Five essays were regarded as of special merit, but only two were elected to share in the prize.[22]

The role of the prize essay in the history of science has not yet been fully explored. Prizes are still awarded today for essays or scientific papers, but they are usually on subjects of the author's own choice, while the 18th century prize was on a subject announced in advance and open to international competition. Contestants submitted their papers anonymously to the society's secretary with some kind of device to identify them later, usually a Latin motto. They resemble to some extent the graduation dissertation, an academic tradition centuries old. In fact, the Akademie der Wissenschaften in Berlin published a collection of their

prize essays in 1748 under the title *Dissertations qui a remporté le prix.* Societies were careful to preserve the anonymity of the author in order not to be influenced by his reputation. The mathematician Daniel Bernoulli nevertheless was awarded the prize by the Academie des Sciences 10 times in the 18th century. The attempt to preserve anonymity was in keeping with their efforts to eliminate personal bias not only in judgment of research results but in the observation of nature. It is interesting that this period, characterized as one of the depersonalization of science, was accompanied by a greater emphasis on priority which gave rise to a number of acrimonious disputes in this period. It reminds us of Merton's discussion of the clash between the social norms of science and the personal needs of the scientist,[23] and Kuhn's comments about the "essential tension" in science.[24]

Almost half of the learned and scientific journals which appeared in the 18th century were published in German, a phenomenon attributed to a German quality which has been described as *schreiblustigkeit,* or joy in writing, and to the highly decentralized nature of the German speaking states at that time, in which each provincial state created its own journals. It also reflects the parochial nature of many of these publications because German was a language not widely used outside of its sphere of dominance. Latin dominated scholarly writing until about 1600, when such vernacular languages as French and English began to be used more frequently in scholarly writing. In the 18th century French assumed ascendancy, but this came from social and political factors as much as scientific ones. French retained its dominance in the first part of the 19th century because of the outstanding contributions of its scientists and physicians, but gradually gave way to German until at the end of the 19th century it was almost mandatory for any serious scientific worker to read German.

This phenomenon has been said to have been produced by the great increase in productivity among German scientists. One of the strong reasons for this phenomenon, says the sociologist Ben-David,[25] was the decentralization of the German universities, which, like the proliferation of German journals, was a consequence of the political decentralization which existed when they were created. The existence of a large number of academic institutions made possible a high degree of mobility among students and teachers. This in turn produced a scientific competition not duplicated elsewhere. It was accompanied, Ben-David says, by a change from the dominance of *Naturphilosophie,* a philosophic way to look at

natural phenomena, to greater emphasis on experimental science. This in turn led to recognition of the university as a seat of scientific research and to the creation of scientific institutes, all of which figured in the competition for faculty. American universities with graduate programs in the sciences tended to model themselves on the German universities during this period. This change, Ben-David concludes, created some of the conditions under which American science assumed ascendancy in the 20th century, until English rather than German is now the predominant language of the scientific world.

Many journals that began during the latter half of the 19th century bear the names of outstanding scientists of this period like *Wilhelm Roux' Archiv fur Entwicklungsmechanick der Organismen,* which began in 1865. These were not merely honorific titles because in most cases they were inaugurated by scientists who took personal editorial responsibility for them. This tradition of concern for the literature by eminent scientists has an old tradition and is, indeed, a hallmark of professional status. The Swiss physician, physiologist, botanist, and poet Albrecht von Haller (1708–1777) has been called by William Osler "the greatest bibliographer in our ranks." Early in his life Haller developed the practice of systematically reading and abstracting the literature. This activity culminated in his eight volume textbook on physiology[26] and in his monumental bibliographies in anatomy, surgery, medicine, and botany. One biographer credits him with having written 12,000 book reviews for the *Göttinger Gelehrte Anzeiger* during his tenure at the university from 1745 to 1777. This would average out to about 400 reviews a year, a formidable achievement even for a genius like Haller, considering the other things he was doing, like developing a theory of tissue irritability. Fortunately for our sense of credulity, a later scholar found that his biographer had been overcome by admiration and added an extra zero to the 1,200 reviews with which he had originally been credited.[27]

Many leaders in biology and medicine began journals in this period to create outlets for their own work and for that of their colleagues and students. The German anatomist and physiologist Rudolf Albert von Kölliker (1817–1905) founded the *Zeitschrift fur wissenschaftliche Zoologie* in 1848 and edited it for half a century. Rudolf Carl Virchow (1821–1902), probably the best known German physician of his time, who, as the founder of cellular pathology, contributed greatly toward the scientific basis of modern medicine, began the *Archiv für pathologische Anatomie und Physiologie* in 1845 and remained its editor until his death.

It became known after his death as *Virchow's Archiv.* This is also true for other outstanding journals of the period such as that of Albrecht von Graefe (1828–1870), who made numerous contributions in ophthalmology and edited the *Archiv für klinische und experimentelle Ophthalmologie;* Felix Hoppe-Seyler (1825–1895), who occupied the first chair of physiological chemistry in Germany and edited the *Zeitschrift für physiologische Chemie;* and Carl Gegenbaur (1826–1903), the anatomist who was responsible for the *Morphologischen Jahrbuch.* These journals today publish largely in English, and some have even acquired English titles.

It has been estimated that the number of journals increased from about 900 in 1800 to almost 60,000 in 1901.[28] During this period the scientific journal changed from primarily a news and book review medium to a vehicle and repository for scientific research. It did not lose any of its old functions while adding new ones, but did undergo specialization and diversification which produced the complex and cumbersome system we know today.

One of the consequences of this growth has been the increase in secondary media, that is, publications based on antecedent publications and presenting guides or digests (another biological term) to enable scientists better to gain access to or to control the burgeoning literature. Efforts to present summaries or syntheses of the current state of knowledge (''state of the art reviews'' as we say today) go back to the beginnings of recorded knowledge. The great encyclopedic compendia of the classical and medieval periods, such as Roman Pliny's (23–79) *Natural History,* Isidore of Seville's *Etymologiae,* and the Franciscan known as Bartholomew the Englishman's (c1260) *On the Properties of Things,* represent efforts of this kind.

With the proliferation of journals during the 18th century, anxieties began to be expressed about the difficulty of gaining access to the literature. One new technique introduced at this time was the abstract journal. A journal published in Mannheim in 1760 describes the function of this new medium in its title: *Journal des Journaux; ou Précis des Principaux Ouvrages Périodiques de l'Europe* (Journal of Journals; or a Summary of the Periodical Works of Europe). The new medium met a real need because the number of active abstract journals in all fields increased from 9 in 1790 to 249 in 1920.[29] Germany dominated these services in the sciences until World War I, when many of these publications were suspended and did not resume. The *Chemischer*

Zentralblatt, begun in 1830, established a model for a series of *Zentralblatter* in various disciplines, some of which lasted for only a few years but many of which continued for decades.

Other efforts to organize and synthesize the literature took the form of progress reports and annual reviews which took such names as *Jahresbericht* (annual report) such as the *Jahresbericht über die Leistungen und Forschritte im Gebiete der Ophthalmologie* which began in 1870. They also began with such terms as *Jahrbuch* (yearbook), *Ergebnisse* (results), and *Fortschritte* (advances), all with cognates in English and other languages.

The first efforts to index the journal literature took place almost immediately after the first journals appeared. An obscure Flemish bookseller named Cornelius a Beughem published an index to the *Journal des Sçavans* in 1683 under the title *La France Sçavante.* Like all Gaul, it was divided into three parts: a chronological part in which the contents of each issue are listed by date of publication, an author index, and finally a classified subject index. It is interesting that the *Current List of Medical Literature,* published by the National Library of Medicine from 1941 to 1959, was in almost the same format. Beughem followed his single journal index with an index to a larger number of journals which included the *Philosophical Transactions* in its Latin edition, the *Acta Eruditorum,* a Latin equivalent of the *Journal des Sçavans* published in Germany, and seven other journals. Many other indices, either on a current or retrospective basis, appeared during the 18th and 19th century. They culminated in a large retrospective index which the Royal Society began to publish in 1858 to cover the scientific literature in all disciplines published since 1800 under the title *Catalogue of Scientific Papers.* Later in the century the National Library of Medicine (then the Library of the Surgeon General's Office) began to publish the monumental *Index Catalogue of the Library,* which, although primarily devoted to medicine, is of interest to all the life sciences. It appeared in five series from 1896 to 1961 when it was discontinued when it was decided that it could not keep pace with the growth of the medical literature. These publications are still of great use for historians of science or investigators looking for early antecedents of scientific ideas. They represent precursors and prototypes of a host of publications in all disciplines in the life sciences, many of which are now being mediated by a powerful new tool which has only just recently become available to provide a new technology for dealing with some of the problems of control and access to the literature,

the computer. The social and intellectual factors which produced them, however, cannot be ignored in considering the direction which the evolution of the media of scientific communication are taking us today.

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